SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, KAZUNARI TONAMI, a
citizen of Japan residing at Kanagawa, Japan and
HIROSHI TAKAHASHI, a citizen of Japan residing at
Kanagawa, Japan have invented certain new and useful
improvements in

IMAGE PROCESSING METHOD, IMAGE PROCESSING APPARATUS,
IMAGE FORMING METHOD AND RECORDING MEDIUM

of which the following is a specification:-

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to an image forming method, an image processing method and an image processing apparatus using an error diffusion method in multi-level quantization for multi-tone images.

2. Description of the Related Art

For example, in laser printers, digital copiers, display devices, and other various image processing apparatuses, an error diffusion method has been widely used for falsely reproduicng tones of multi-tone images.

With regard to the error diffusion method, the following various improvements have been proposed:

(1) In a system in which image data is two-level quantized according to the error diffusion method, in order to improve continuity of characters and figures, a configuration (continuity) of ON dots output in the periphery of a target pixel is examined, and a quantization threshold is controlled so that an output dot of the target pixel is easily to generate an ON dot when ON dots continue in a certain direction (Japanese Patent Publication No. 8-24338);

(2) In a system in which image data is two-

level quantized according to the error diffusion method,
in order to prevent a peculiar texture due to close
placement of ON dots due to error diffusion in a
positive direction from occurring in a light shade

5   portion, a quantization threshold is controlled so that
an output dot of a target pixel is determined to be an
OFF dot when ON dots are output in the periphery of the
target dot in a light shade portion (Japanese Patent No.
2662402); and

10   (3) Continuity of output dots in the periphery
of a target pixel is examined, and a quantization
threshold is controlled so that continuity of ON dots or
OFF dots is avoided so that chain-like textures and
false contours are prevented from being generated

15 (Japanese Patent No. 2756308).

SUMMARY OF THE INVENTION

          Although various improvements have been
proposed so as to make up for problems of the error

20 diffusion method, an object of the present invention is
to provide novel method and apparatus for solving
problems of the error diffusion method by an approach
different from those technologies.

          Specifically, as will be described in detail,

25 in a case where multi-tone image data is multi-level

quantized according to ordinary error diffusion, and the thus-obtained quantized data is provided to an electrophotographic printer, for example, so that an image is formed therefrom, the image easily becomes

5 unstable in medium and dark shade regions, tonality skipping easily occurs, saturation of shade easily occurs early, and so forth. Further, in a case where images in which character regions, halftone-dot regions and photograph regions are mixed are handled, image

10 quality may be degraded depending on particular regions. Accordingly, an object of the present invention is to provide novel image forming method, image processing method and image processing apparatus in order to solve these problems.

15 An image forming method, according to the present invention, comprises the steps of:

a) multi-level quantizing a multi-tone image by an error diffusion method; and

b) representing each pixel of the thus-

20 quantized image having a quantized level higher than 0 using a dot which is larger as the quantized level thereof is higher,

wherein occurrence of dots having a specific size is repressed in a specific shade region relating to

25 the dots.

Thereby, by repressing occurrence of dots which result in degrading stability, graininess and tonality of images, it is possible to form images in high quality.

Further, occurrence of the smallest dots may be repressed.

Thereby, it is possible to achieve both satisfactory graininess and stability for light and medium shade regions.

Occurrence of the dots other than the largest dots may be repressed.

Thereby, it is possible to achieve satisfactory graininess for light shade regions, satisfactory stability, graininess and tonality for medium shade regions, and satisfactory stability and tonality for dark shade regions.

An occurrence rate of the dots having the specific size may be controlled based on the number of dots in a specific region in the periphery of a target pixel.

Thereby, it is possible to, based on the number of dots in the periphery of a target pixel, control a occurrence rate of specific dots so that a mixing rate of dots changes smoothly with respect to tonality change, thereby, it is possible to perform

tonality representation with the most suitable dot occupancy rate, and, also, to form smooth images with a little tonality skipping or incongruity at positions at which size of dots is switched.

An occurrence rate of the dots having the specific size may be controlled based on the number of dots in a specific region in the periphery of a target pixel and a shade level of the target pixel.

Thereby, it is possible to suitably control a dot occurrence rate in consideration to the shade level of a target pixel, and to perform tonality representation with the most suitable dot occupancy rate.

An occurrence rate of the dots having the specific size may be controlled based on the number of dots having a specific size in a specific region in the periphery of a target pixel.

An occurrence rate of the dots having the specific size may be controlled based on the number of dots having a specific size in a specific region in the periphery of a target pixel and a shade level of the target pixel.

Thereby, it is possible to perform control such that, in a case of 4-level quantization, even when many large dots exist in the periphery of a target pixel, an occurrence rate of the smallest dots is not reduced

when other dots are few. Accordingly, it is possible to form images with a little jaggy at character (or letter) portions or edge portions of images and satisfactory sharpness.

5   A degree of repressing occurrence of the dots having the specific size may be changed according to a feature of the image.

Thereby, it is possible to repress occurrence of dots in an appropriate degree for various images having different features, and to perform tonality
10   representation with an appropriate dot occupancy rate.

Occurrence of the dots having the specific size may be repressed only for a picture region of the image.

Thereby, it is possible to improve stability
15   and tonality for picture regions of images.

The degree of repressing occurrence of the dots having the specific size may be made weaker for a character region of the image than for a picture region
20   of the image.

Thereby, it is possible to form images in which character regions and picture regions are mixed, character regions having satisfactory sharpness and picture regions having satisfactory stability and
25   tonality.

Occurrence of the dots having the specific size may be repressed only for a non-edge region of the image.

Thereby, it is possible to improve sharpness for edge regions of images, and to improve stability and tonality for non-edge regions.

Repressing of occurrence of the dots having the specific size may be performed for a medium shade region of the image.

Thereby, it is possible to form images having satisfactory graininess in light shade regions, and satisfactory stability and tonality in medium shade regions.

Repressing of occurrence of the dots having the specific size may be performed for a dark shade region of the image.

Thereby, it is possible to form images having satisfactory graininess in light shade regions, and satisfactory stability and tonality in dark shade regions.

Repressing of occurrence of the dots having the specific size may be performed for medium and dark shade regions of the image.

Thereby, it is possible to form images having satisfactory graininess in light shade regions, and

satisfactory stability and tonality in medium and dark shade regions.

An image processing method, according to another aspect of the present invention, comprises the
5   steps of:

a) multi-level quantizing multi-level input image data; and

b) repressing occurrence of one or more specific quantized levels for a specific level region of
10   the image data relating to the one or more specific quantized levels.

Re-quantization may be performed for the one or more specific quantized levels, occurrence of which is to be repressed.

15   By multi-level quantizing multi-level input image data through this image processing method, and representing it using dots for pixels which dots are larger as the pixels have higher quantized levels, it is possible to form high-quality images according to the
20   image forming method described above.

Occurrence of the one or more specific quantized levels may be repressed for a medium level region of the image data.

Occurrence of the one or more specific
25   quantized levels may be repressed for a high level

region of the image data.

Occurrence of the one or more specific quantized levels may be repressed for medium and high level regions of the image data.

5   An occurrence rate(s) of the quantized level(s), occurrence of which is to be repressed, may be controlled based on the number of pixels quantized to be higher than quantized level 0 in a specific region in the periphery of a target pixel.

10   An occurrence rate(s) of the quantized level(s), occurrence of which is to be repressed, may be controlled based on the number of pixels quantized to be higher than the quantized level 0 in a specific region in the periphery of a target pixel and the level of the 15 image data of the target pixel.

An occurrence rate(s) of the quantized level(s), occurrence of which is to be repressed, may be controlled based on the number of pixels quantized to a specific quantized level in a specific region in the 20 periphery of a target pixel.

An occurrence rate(s) of the quantized level(s), occurrence of which is to be repressed, may be controlled based on the number of pixels quantized to a specific quantized level in a specific region in the 25 periphery of a target pixel and the level of the image

data of the target pixel.

A degree(s) of repressing occurrence of the one or more specific quantized levels may be changed according to a feature of the image.

5   Occurrence of the one or more specific quantized levels may be repressed only for a picture region of the image.

The degree(s) of repressing occurrence of the one or more specific quantized levels may be made weaker

10   for a character region of the image than for a picture region of the image.

Occurrence of the one or more specific quantized levels may be repressed only for a non-edge region of the image.

15   Re-quantization may be performed for the one or more specific quantized levels, occurrence of which is to be repressed.

An image forming method, according to another aspect of the present invention, comprises the steps of:

20   a) multi-level quantizing multi-level input image data by the image processing method as described above; and

b) forming an image from the thus-multi-level-quantized image data using dots for pixels which dots

25   are larger as the pixels have higher quantized levels.

An image processing apparatus, according to the present invention, comprises:

a first part multi-level quantizing multi-tone image data; and

5   a second part repressing occurrence of one or more specific quantized levels for a specific level region of the image data relating to the one or more specific quantized levels.

Thereby, it is possible to perform multi-level quantization of multi-level input image data by the above-described image processing method. Accordingly, by providing the output image data to an image forming part which forms images using dots for pixels which dots are larger as the pixels have higher quantized levels, it is possible to form high-quality images according to the above-described image forming method.

The second part may perform re-quantization for the one or more specific quantized levels, occurrence of which is to be repressed.

The second part may repress occurrence of the one or more specific quantized levels for a medium level region of the image data.

The second part may repress occurrence of the one or more specific quantized levels for a high level region of the image data.

The second part may repress occurrence of the one or more specific quantized levels for medium and high level regions of the image data.

The second part may control an occurrence rate(s) of the quantized level(s), occurrence of which is to be repressed, based on the number of pixels quantized to be higher than the quantized level 0 in a specific region in the periphery of a target pixel.

The second part may control an occurrence rate(s) of the quantized level(s), occurrence of which is to be repressed, based on the number of pixels quantized to be higher than the quantized level 0 in a specific region in the periphery of a target pixel and the level of the image data of the target pixel.

The second part may control an occurrence rate(s) of the quantized level(s), occurrence of which is to be repressed, based on the number of pixels quantized to a specific quantized level in a specific region in the periphery of a target pixel.

The second part may control an occurrence rate(s) of the quantized level(s), occurrence of which is to be repressed, based on the number of pixels quantized to a specific quantized level in a specific region in the periphery of a target pixel and the level of the image data of the target pixel.

The second part may change a degree(s) of repressing occurrence of the one or more specific quantized levels according to a feature of the image.

The second part may repress occurrence of the one or more specific quantized levels only for a picture region of the image.

The second part may make the degree(s) of repressing occurrence of the one or more specific quantized levels weaker for a character region of the image than for a picture region of the image.

The second part may repress occurrence of the one or more specific quantized levels only for a non-edge region of the image.

The second part may change a degree(s) of repressing occurrence of the one or more specific quantized levels according to a specified output mode.

Thereby, it is possible to change a degree(s) of repressing occurrence of one or more specific quantized levels by selecting the output mode, and, thereby, to form various types of images to have high quality.

The second part may perform re-quantization for the one or more specific quantized levels, occurrence of which is to be repressed.

An image processing apparatus, according to

another aspect of the present invention, comprises:

a first part adding an error to input image data;

a second part multi-level quantizing the image
5   data to which the error is already added by the first
part, using a plurality of quantization thresholds;

a third part re-quantizing the quantized data
into another quantized level, provided by the second
part, for one or more specific quantized levels other
10   than the highest quantized level and quantized level 0,
as the need arises, and outputting the thus-obtained
data as an output image data;

a fourth part obtaining the error to be added
to the input image data, from the output image data and
15   image data to which the error is already added by the
first part, and providing the thus-obtained error to the
first part; and

a fifth part detecting, from the output image
data, the number of pixels quantized to the quantized
20   levels equal to or higher than the quantized level 1 in
a specific region in the periphery of a target pixel,
and providing the thus-obtained number to the third part,

wherein the third part compares a threshold
relating to each of the one or more specific quantized
25   levels determined based on the number provided by the

fifth part, with the level of the image data to which

the error is already added, and, thereby, determines

whether re-quantization for the each of the one or more

specific quantized levels is necessary, occurrence of

5   each of the one or more specific quantized levels being

repressed in a specific level region of the input image

data relating to the each of the one or more specific

quantized levels through the re-quantization by the

third part.

10   Thereby, it is possible to perform multi-level

quantization of multi-tone image data by the above-

described image processing method. Accordingly, by

providing the output image data to an image forming part

which forms images using dots for pixels which dots are

15   larger as the pixels have higher quantized levels, it is

possible to form high-quality images according to the

above-described image forming method.

          The third part may determine that re-

quantization is not necessary when the level of the

20   input image data is out of the specific level region

relating to each of the one or more specific quantized

levels.

          Thereby, it is possible to exclude a target

pixel not having a intermediate level which occurs less

25   frequently in high-contrast images such as those of

general business documents, from object of re-
quantization, to reduce the process time, and, also, to
prevent line cut-out of low-contrast characters
(letters).

An image processing apparatus, according to
another aspect of the present invention, comprises:

a first part adding an error to input image
data;

a second part multi-level quantizing the image
data to which the error is added by the first part,
using a plurality of quantization thresholds;

a third part re-quantizing the quantized data
provided by the second part, into another quantized
level, for one or more specific quantized levels other
than the highest quantized level and quantized level 0,
as the need arises, and outputting the thus-obtained
data as an output image data;

a fourth part obtaining the error to be added
to the input image data, from the output image data and
the image data to which the error is already added by
the first part, and providing the thus-obtained error to
the first part; and

a fifth part detecting, from the output image
data, the number of pixels quantized to the quantized
levels equal to or higher than the quantized level 1 in

a specific region in the periphery of a target pixel,

and providing the thus-obtained number to the third part,

wherein the third part compares a threshold

relating to each of the one or more specific quantized

5   levels determined based on the number provided by the

fifth part and the level of the input image data, with

the level of the image data to which the error is

already added, and, thereby, determines whether re-

quantization for the each of the one or more specific

10 quantized levels is necessary, occurrence of each of the

one or more specific quantized levels being repressed in

a specific level region of the input image data relating

to the each of the one or more specific quantized levels

through the re-quantization by the third part.

15   Thereby, it is possible to perform multi-level

quantization of multi-tone image data by the above-

described image processing method. Accordingly, by

providing the output image data to an image forming part

which forms images using dots for pixels which dots are

20 larger as the pixels have higher quantized levels, it is

possible to form high-quality images according to the

above-described image forming method.

An image processing apparatus, according to

another aspect of the present invention, comprises:

25   a first part adding an error to input image

data;

a second part multi-level quantizing the image data to which the error is added by the first part, using a plurality of quantization thresholds;

5   a third part re-quantizing the quantized data provided by the second part, into another quantized level, for one or more specific quantized levels other than the highest quantized level and quantized level 0, as the need arises, and outputting the thus-obtained

10   data as an output image data;

a fourth part obtaining the error to be added to the input image data from the output image data and the image data to which the error is already added by the first part, and providing the thus-obtained error to

15   the first part; and

a fifth part detecting, from the output image data, the number of pixels for each quantized level in a specific region in the periphery of a target pixel, and providing the thus-obtained number to the third part,

20   wherein the third part compares a threshold relating to each of the one or more specific quantized levels determined based on the total number of pixels of each of the one or more specific quantized levels and one or more other quantized levels near the each of the

25   one or more specific quantized levels and the level of

the input image data, with the level of the image data
to which the error is already added, and, thereby,
determines whether re-quantization for the each of the
one or more specific quantized levels is necessary,

5   occurrence of each of the one or more specific quantized
levels being repressed in a specific level region of the
input image data relating to the each of the one or more
specific quantized levels through the re-quantization by
the third part.

10   Thereby, it is possible to perform multi-level
quantization of multi-tone image data by the above-
described image processing method. Accordingly, by
providing the output image data to an image forming part
which forms images using dots for pixels which dots are

15   larger as the pixels have higher quantized levels, it is
possible to form high-quality images according to the
above-described image forming method.

An image processing apparatus, according to
another aspect of the present invention, comprises:

20   a first part adding an error to input image
data;

a second part multi-level quantizing the image
data to which the error is added by the first part,
using a plurality of quantization thresholds;

25   a third part re-quantizing the quantized data

provided by the second part, into another quantized
level, for one or more specific quantized levels, as the
need arises, and outputting the thus-obtained data as an
output image data;

5   a fourth part obtaining the error to be added
to the input image data, from the output image data and
image data to which the error is already added by the
first part, and providing the thus-obtained error to the
first part; and

10   a fifth part detecting, from the output image
data, the number of pixels quantized to the quantized
levels equal to or higher than the quantized level 1 in
a specific region in the periphery of a target pixel,
and providing the thus-obtained number to the third part,

15   wherein the third part has a signal indicating
a feature of an image region to which the target pixel
belongs input thereto externally, and compares a
threshold relating to each of the one or more specific
quantized levels determined based on a parameter

20 relating to the each of the one or more specific
quantized levels determined according to the feature
indicated by the signal, the number provided by the
fifth part and the level of the input image data, with
the level of the image data to which the error is

25 already added, and, thereby, determines whether re-

quantization for the each of the one or more specific quantized levels is necessary, occurrence of each of the one or more specific quantized levels being repressed in a degree according to said feature in a specific level

5 region of the input image data relating to the each of the one or more specific quantized levels through the re-quantization by the third part.

Thereby, it is possible to perform multi-level quantization of multi-tone image data by the above-

10 described image processing method. Accordingly, by providing the output image data to an image forming part which forms images using dots for pixels which dots are larger as the pixels have higher quantized levels, it is possible to form high-quality images according to the

15 above-described image forming method.

The signal may indicate whether the image region to which the target pixel belongs is a character region or a picture region; and

the parameter relating to each of the one or

20 more specific quantized levels may be determined such that occurrence of the each of the one or more specific quantized levels is repressed only for the picture region.

The signal may indicate whether the image

25 region to which the target pixel belongs is a character

region or a picture region; and

the parameter relating to each of the one or
more specific quantized levels may be determined such
that a degree of repressing occurrence of the each of

5   the one or more specific quantized levels is weaker for
the character region than for the picture region.

The signal may indicate whether the image
region to which the target pixel belongs is an edge
region or a non-edge region; and

10   the parameter relating to each of the one or
more specific quantized levels may be determined such
that occurrence of the each of the one or more specific
quantized levels is repressed only for the non-edge
region

15   An image processing apparatus, according to
another aspect of the present invention, comprises:

a first part adding an error to input image
data;

a second part multi-level quantizing the image
20   data to which the error is added by the first part,
using a plurality of quantization thresholds;

a third part re-quantizing the quantized data
provided by the second part into another quantized level,
for one or more specific quantized levels, as the need
25   arises, and outputting the thus-obtained data as an

output image data;

a fourth part obtaining the error to be added to the input image data, from the output image data and image data to which the error is already added by the first part, and providing the thus-obtained error to the first part; and

a fifth part detecting, from the output image data, the number of pixels quantized to the quantized levels equal to or higher than the quantized level 1 in a specific region in the periphery of a target pixel, and providing the thus-obtained number to the third part,

wherein the third part has a signal indicating an output mode input from the outside, and compares a threshold relating to each of the one or more specific quantized levels determined based on a parameter relating to the each of the one or more specific quantized levels determined according to the output mode indicated by the signal, the number provided by the fifth part and the level of the input image data, with the level of the image data to which the error is already added, and, thereby, determines whether re-quantization for the each of the one or more specific quantized levels is necessary, occurrence of each of the one or more specific quantized levels being repressed in a degree according to said output mode in a specific

level region of the input image data relating to the

each of the one or more specific quantized levels

through the re-quantization by the third part.

Thereby, it is possible to perform multi-level

5   quantization of multi-tone image data by the above-

described image processing method. Accordingly, by

providing the output image data to an image forming part

which forms images using dots for pixels which dots are

larger as the pixels have higher quantized levels, it is

10   possible to form high-quality images according to the

above-described image forming method.

Further, it is possible to change a degree(s)

of repressing occurrence of one or more specific

quantized levels by selecting the output mode, and,

15   thereby, to form various types of images to have high

quality

The second part may perform 4-level

quantization;

the re-quantization performed by the third

20   part may be performed for the quantized level 1; and

occurrence of the quantized level 1 may be

repressed for a medium level region of the input image

data.

The second part may perform 4-level

25   quantization;

the re-quantization performed by the third part may be performed for the quantized level 1 and quantized level 2;

occurrence of the quantized level 1 may be repressed in a medium level region of the input image data; and

occurrence of the quantized level 2 may be repressed in a high level region of the input image data.

The image processing apparatus may further comprise a sixth part generating the signal input to the third part.

The image processing apparatus may further comprise a sixth part which forms, from the image output data, an image using dots for pixels which dots are larger as the pixels have higher quantized levels.

The image processing apparatus may further comprise a sixth part generating the input image data by optically scanning an original.

The image processing apparatus may further comprise:

a sixth part generating the input image data by optically scanning an original; and

a seventh part forming, from the image output data, an image using dots for pixels which dots are larger as the pixels have higher quantized levels.

Thereby, it is possible to achieve a printer, a display, a scanner, a facsimile machine and a digital copier, which handle multi-tone images, and provide high image quality.

5   A computer-readable recording medium, according to the present invention, stores therein a program for causing a computer to carry out the function of each part of the image processing apparatus described above.

10   Thereby, it is possible to easily achieve the image processing apparatus described above using a general-purpose or special purpose computer.

Other objects and further features of the present invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing one example of a block configuration of an image processing apparatus according to the present invention;

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FIG. 2 is a flow chart showing one example of processing performed by an output dot control part of the image processing apparatus according to the present invention;

25   invention;

FIG. 3 shows a relationship between input image data levels and occurrence rates of quantized levels 1, 2 and 3, in a case of ordinary 4-level error diffusion process;

5   FIG. 4 shows one example of a relationship between input image data levels and occurrence rates of quantized levels 1, 2 and 3, in a case of 4-level error diffusion process according to the present invention;

FIG. 5 is a block diagram showing another

10 example of a block configuration of an image processing apparatus according to the present invention;

FIGS. 6 and 7 are flow charts showing other examples of processing performed by an output dot control part of the image processing apparatus according

15 to the present invention;

FIG. 8 shows another example of a relationship between input image data levels and occurrence rates of quantized levels 1, 2 and 3, in a case of 4-level error diffusion process according to the present invention;

20   FIG. 9 is a flow chart showing another example of processing performed by the output dot control part of the image processing apparatus according to the present invention;

FIG. 10 is a block diagram showing another

25 example of a block configuration of an image processing

apparatus according to the present invention;

FIGS. 11 and 12 are flow charts showing other examples of processing performed by an output dot control part of the image processing apparatus according to the present invention;

FIG. 13 is a block diagram showing another example of a block configuration of an image processing apparatus according to the present invention;

FIG. 14 illustrates selectable output modes and corresponding values of parameters A and B in the image processing apparatus according to the present invention;

FIG. 15 shows dot occurrence states obtained from ordinary 4-level error diffusion process and dot occurrence states obtained from 4-level error diffusion process according to the present invention;

FIG. 16 is a general sectional view showing one example of a digital copier according to the present invention;

FIGS. 17 and 18 are block diagrams showing examples of a configuration of a circuit part inside of the digital copier shown in FIG. 16;

FIGS. 19A, 19B, 19C and 19D show one example of differential filters for edge detection; and

FIG. 20 shows a block diagram of a general-

purpose or special-purpose computer by which an image processing apparatus according to the present invention can be achieved.

5   DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Image processing apparatuses in embodiments of the present invention will now be described with reference to accompanying drawings.

By the image processing apparatuses according
10   to the present invention which will be described, image processing methods according to the present invention can be put into practice, and, also, image formation can be performed when output image data obtained from the image processing apparatuses are provided to image
15   forming parts which form images by using dots which are larger for pixels having higher quantized levels.

In order to avoid duplication of description, the same reference numerals are given to the same parts or corresponding parts through a plurality of drawings.

20

<<First Embodiment>>

An image processing apparatus in a first embodiment of the present invention has a block configuration shown in FIG. 1, and, basically, quantizes
25   input image data 100 of 8 bits/pixel into four levels, i.

e., 0, 1, 2 and 3, according to an error diffusion method, and outputs thus-quantized data as output image data 101. The output values corresponding to the quantized levels 0, 1, 2 and 3 are 0, 85, 170, 255

5   (decimal notation), respectively.

Basic parts for such four-level quantization according to the error diffusion method are an error adding part 110 which adds a diffusion error to the input image data 100, a quantization part 111 which

10   outputs the quantized levels 0, 1, 2 and 3 by comparing the image data to which the diffusion error is thus already added by the error adding part 110, with three quantization thresholds T1, T2 and T3 (T1 < T2 < T3), an error calculating part 112 which calculates an error

15   between the output image data 101 and image data 102 to which the error is thus already added, an error storage part 113 which temporarily stores the thus-calculated error, and a diffusion error calculating part 114 which calculates the diffusion error for a pixel (target

20   pixel) to be processed subsequently, using the error data stored in the error storing part 113 and provides the diffusion error to the error adding part 102.

The above-mentioned quantization thresholds T1, T2 and T3 are determined to be approximately

25   intermediate values between adjacent two quantized

levels, and, for example, T1 = 43, T2 = 128, and T3 = 213.

In the first embodiment, as indicated by the inside of the block of the diffusion error calculating part 114, * (asterisk) indicates a position of a target pixel, errors calculated for pixels at respective positions of 'a', 'b' and 'c' on the immediately preceding line and the pixel at the immediately preceding position 'd' on the same line of the target pixel are used for calculating the diffusion error for the target pixel.

The diffusion error calculating part 114 multiplies the errors calculated for the pixels at the above-mentioned positions 'a', 'b', 'c' and 'd' with coefficients 1, 5, 3 and 7, respectively, and the sum of the thus-obtained values is divided by 16. The thus-obtained value is output as the diffusion error for the target pixel (*) by the diffusion error calculating part 114.

Accordingly, as the error storage part 113, a line memory having two lines is used, for example.

Further, the above-mentioned configuration and number of pixels in the periphery of the target pixel to be referred to for calculating the diffusion error can be changed, and, also, the above-mentioned coefficients

for the errors of those pixels can be changed.

Further, the following configuration can also be employed, instead: A calculating part corresponding to the diffusion error calculating part 114 is provided

5   between the error calculating part 112 and error storage part 113, the diffusion errors for not-yet-processed peripheral pixels are re-calculated one by one by this calculating part using the errors calculated by the error calculating part 112 and error data stored in the

10 error storage part 113, the error data stored in the error storage part 113 is updated by this calculation result, and the diffusion error for the pixel to be processed subsequently is read directly from the error storage part 113 and is provided to the error adding

15 part 110.

In the image processing apparatus in the first embodiment, in addition to those basic parts for the four-level error diffusion process described above, a peripheral dot information storage part 117, a

20 peripheral dot counting part 118, and an output dot control part 119 are provided, and, thereby, one which is obtained through re-quantization as the need arises by the output control part 119 for specific quantization level(s) is output as the output image data 101. It is

25 also possible to integrate the output dot control part

119 with the quantization part 111.

The peripheral dot information storage part 117 temporarily stores dot information expressed by 1 bit/pixel as to whether each already quantized pixel

5 within a fixed region in the periphery of a target pixel has the quantized level 0 or more than 0.

An image forming method according to the present invention can be put into practice as a result of the output image data 101 being provided to an image

10 forming apparatus such as an electrophotographic printer which forms images by using larger dots for pixels having higher quantized levels.

In this case, no dot is formed for a pixel having the quantized level of 0, and a dot having a size

15 according to the quantized level is formed for a pixel having the quantized level more than 0.

Accordingly, in the specification and claims, a pixel having the quantized level 0 in the output image data 101 may be referred to as an OFF-dot, and a pixel

20 having the quantized level more than 0 may be referred to as an ON-dot. By using this expression, in the peripheral dot information storage part 117, a pixel of OFF dot is represented by "0", and a pixel of ON dot is represented by "1", for example.

25   The peripheral dot counting part 118 refers to

the dot information stored in the peripheral dot information storage part 117, and counts the number of ON dots in the specific region in the periphery of a target pixel.

5   In the first embodiment, assuming that * (asterisk) shown inside of the block of the peripheral dot information storage part 117 indicates a position of a target pixel to be processed, the number of ON dots (the number of peripheral dots) is counted for the

10   peripheral ten pixels shown in the block in the figure. Accordingly, as the peripheral dot information storage part 117, a line memory having two lines is used, for example.

     That is, in the first embodiment, the

15   peripheral dot counting part 118 and peripheral dot information storage part 117 are used for detecting the number of pixels which have been quantized to the quantized levels more than 0 for the specific region in the periphery of a target pixel. The number and

20   configuration of pixels in the periphery of a target pixel for which dot information is referred to by the peripheral dot counting part 118 can be changed as the need arises.

     The output dot control part 119 has the input

25   data (the image data 102 after having the error added

thereto) of the quantization part 111, the quantization output of the quantization part 111, and the number of peripheral dots counted by the peripheral dot counting part 118 input thereto, and executes the process shown

5   in FIG. 2.

This process will now be described with reference to FIG. 2.

First, in a step S1, it is determined whether or not the quantization output of the quantization part

10   111 for a target pixel is the quantized level 1 (output value: 85). Then, when it is not the quantized level 1, the quantization output of the quantization part 111 is output as it is (in a step S2).

When the quantization output of the

15   quantization part 111 is the quantized level 1, a threshold THR is determined (in a step S3). In the first embodiment, the threshold THR is calculated using the number ('count') of peripheral dots counted by the peripheral dot counting part 118 and a constant by the

20   following equation:

THR = count × constant

For example, the constant is determined to be 10.

25   Then, it is determined in a step S4 whether or

not the level ('level', the level of the image data 102)

is smaller than the threshold THR. When it is not

smaller than the threshold THR, the quantization output

of the quantization part 111 is output as it is (in a

5   step S5). That is, for the current target pixel, it is

determined that re-quantization of the quantized level 1

is not necessary. As the number of ON dots in the

periphery of the target pixel increases, the threshold

THR increases, and a rate of being determined that re-

10   quantization is not necessary decreases. Accordingly,

the quantization level 1 comes to be not easily output.

When the target pixel level 'level' is smaller

than the threshold THR, it is determined that re-

quantization is necessary, and the target pixel level

15   'level' is compared with a threshold relating to the

quantized level 1, and, thereby, re-quantization is

performed. In the first embodiment, it is determined in

a step S6 whether or not the target pixel level 'level'

is smaller than 64 which is an approximately

20   intermediate value between the quantization threshold T1

and the output value 85 of the quantized level 1. Then,

when the target pixel level 'level' is smaller than 64,

the quantized level 0 (output value: 0) is output (in a

step S7). However, when the target pixel level 'level'

25   is not smaller than 64, the quantized level 2 (output

value: 170) is output (in a step S8).

In a case where neither re-quantization nor output dot control described above is performed, and the quantized data of the quantization part 111 is output as

5   it is, that is, the output dot control part 119 is removed, and an ordinary 4-level error diffusion process is performed, the rates (probabilities) of occurrence of the quantized levels 1, 2 and 3 change with respect to the level of the input image data 100 as shown in

10   FIG. 3.

As shown in FIG. 3, when the input image data level increases from 0, the occurrence rate of the quantized level 1 increases, and, when the input image data level becomes 85, the occurrence rate of the

15   quantized level 1 becomes 100 %. When the input image data level exceeds 85, the occurrence rate of the quantized level 1 decreases, and the occurrence rate of the quantized level 2 increases. When the input image data level becomes 170, the occurrence rate of the

20   quantized level 1 becomes 0 %, and the occurrence rate of the quantized level 2 becomes 100 %. When the input image data level exceeds 170, the occurrence rate of the quantized level 2 decreases, and the occurrence rate of the quantized level 3 increases. When the input image

25   data level becomes 255, the occurrence rate of the

quantized level 2 becomes 0 %, and the occurrence rate of the quantized level 3 becomes 100 %.

When the quantized data having this characteristic is provided to an image forming apparatus

5   such as an electrophotographic printer, as shown in FIG. 3, for a medium level region (medium shade region) of the input image data 100, there is a region in which the rate of occurrence of unstable smallest dots of the quantized level 1 is high. In this region, stability

10 and tonality of the image are degraded. Further, for a high level region (dark shade region) of the input image data 100, there is a region in which the rate of occurrence of small dots of the quantized level 2 is high. In this region, stability and tonality of the

15 image are degraded.

On the other hand, in a case where re-quantization or output dot control described above is performed by the output dot control part 119 according to the present invention, the quantized levels 1, 2 and

20 3 occur at the rates with respect to the input image data level shown in FIG. 4.

As shown in FIG. 4, for a region (light shade region) in which the input image data level is low, the occurrence rate of the quantized level 1 increases as

25 the input image data level increases. However, in a

region (medium shade region) in which the input image data level is medium, from the level at which the occurrence rate of the quantized level 1 reaches 50 % (determined by the above-mentioned constant), the

5 occurrence rate of the quantized level 1 decreases sharply, and the occurrence rate of the quantized level 2 increases.

Accordingly, in a case where the output image data 101 is provided to an image forming apparatus such

10 an electrophotographic printer, and images are formed in such a manner that dots are used larger for pixels having higher quantized levels, for a light shade region, images are formed by the smallest dots corresponding to the quantized level 1, and, thereby, isolated dots are

15 not easily remarkable, and graininess is satisfactory.

In a medium shade region in which the small dots of the quantized level 2 occur, occurrence of the unstable smallest dots is repressed, and images are formed approximately only by the small dots of the

20 quantized level 2. Accordingly, stability and graininess of the images are improved. Repressing of occurrence of the smallest dots is controlled according to the number of dots within the specific region in the periphery of a target pixel, and, also, an output dot

25 for the pixel for which occurrence of the smallest dot

is repressed is determined by re-quantization. Accordingly, through all the medium shade region, tonality is represented by an appropriate dot occupation rate, and the number of tones can be increased. Further,

5   the mixing rate of dots is smoothly switched according to tonality change, and thereby, it is possible to form images in which switched portions smoothly couple.

Further, although not shown in figures, in another embodiment of the present invention, as a result

10   of re-quantization or output dot control similar to those of the first embodiment being performed not for the quantized level 1 but for the quantized level 2, occurrence of the small dots of the quantized level 2 is repressed for a dark shade region in which large dots of

15   the quantized level 3 occur. Thereby, as will be described in detail for a third embodiment described later, stability and graininess of the images in dark shade regions are improved.

20   <<Second Embodiment>>

An image processing apparatus in a second embodiment of the present invention has a block configuration similar to that of the first embodiment described above. However, as shown in FIG. 5, also the

25   input image data 100 is input to the output dot control

part 119. Further, the output dot control part 119 executes the process shown in FIG. 6.

This process will now be described with reference to FIG. 6.

First, the output dot control part 119 determines in a step S10 whether or not the level ('LEVEL', the level of the input image data 100) of a target pixel before having the error added thereto is within a range of a medium shade of 30 through 170. When the target pixel level 'LEVEL' is not larger than 30 or not smaller than 170, the quantization output of the quantization part 111 is output as it is (in a step S12).

However, when the target pixel level 'LEVEL' is within the range of 30 through 170, it is determined in a step S11 whether or not the quantization output of the quantization part 111 is the quantized level 1. When it is not the quantized level 1, the quantization output of the quantization part 111 is output as it is (in a step S12). However, when the quantization output is the quantized level 1, a process for re-quantization of the quantized level 1 the same as that of the above-described first embodiment is executed (in steps S13 through S18). The steps S13, S14, S15, S16, S17 and S18 are the same as the steps S3, S4, S5, S6, S7 and S8

shown in FIG. 2.

Thus, in the second embodiment, because the process of re-quantization of the quantized level 1 the same as that of the first embodiment is executed, the occurrence rates of the respective quantized levels with respect to the input image data level are controlled as shown in FIG. 4. However, the re-quantization of the quantized level 1 is not performed when the input image data level goes out of the range of 30 through 170. Accordingly, occurrence of the quantized level 1 is repressed in a region in which the input image data level exceeds 30.

Accordingly, an image forming method according to the present invention can be put into practice when the output image data 101 of the image processing apparatus in the second embodiment is provided to an electrophotographic printer or the like, and, thereby, similarly to the above-described first embodiment, it is possible to form images in which graininess is satisfactory in light shade regions, and stability, graininess and tonality are satisfactory in medium shade regions.

Further, in the second embodiment, output of the smallest dots of the quantized level 1 is repressed only when the input data level (shade level) is within

the range of 30 through 170. Accordingly, line cutting-out or line vanishment of characters (or letters) in low-contrast character regions do not easily occur. Because such medium shade levels occur less frequently

5   in high-contrast images (images such that black characters are present in white background) such as those of business documents, it is advantageous to eliminate such image data from objects of re-quantization at the first step in the output dot control

10 part 119 for saving the process time. This point is especially advantageous in a case where the process is achieved by software.

<<Third Embodiment>>

15 An image processing apparatus in a third embodiment of the present invention has a block configuration the same as that of the second embodiment shown in FIG. 5, but, executes by the output dot control part 119 the process of re-quantization for the

20 quantized level 1 and quantized level 2 as shown in FIG. 7.

This process will now be described with reference to FIG. 7.

First, the output dot control part 119

25 determines in a step S20 whether or not the quantization

output of the quantization part 111 for a target pixel is the quantized level 1 (output value: 85). When it is not the quantized level 1, it is determined in a step S26 whether or not the quantization output of the

5   quantization part 111 is the quantized level 2. When the quantization output is neither the quantized level 1 nor the quantized level 2, the quantization output of the quantization part 111 is output as it is (in a step S34). Accordingly, the quantized level 0 and quantized

10   level 3 are out of objects of re-quantization or output dot control.

       When the quantization output of the quantization part 111 is the quantized level 1 (YES of the step S20), a threshold THR1 relating to the

15   quantized level 1 is determined (in a step S21).

       In the third embodiment, the threshold THR1 is calculated by the following equation:

$$THR1 = 43 + (LEVEL - A) \times count \times CNT1$$

20

As mentioned above, 'LEVEL' denotes the target pixel level of the input image data 100, 'count' denotes the number of peripheral dots counted by the peripheral dot counting part 118, 'A' and 'CNT1' are parameters for

25   determining the input image data level at which the

occurrence rate of the quantized level 1 starts

decreasing and a slope of the decrease (see FIG. 8), and

'CNT1' is determined as 2, for example. Further, '43'

corresponds to the quantization threshold T1.

5   Then, it is determined in a step S22 whether

or not the target pixel level 'level' (level of the

image data 102) after having the error added thereto is

larger than the threshold THR1. When it is larger than

the threshold THR1, it is determined that re-

10 quantization for the quantized level 1 for the target

pixel is not necessary, and the quantized level 1

(output value: 85) is output as it is (in a step S23).

When the target pixel level exceeds A, the threshold

THR1 increases as this level increases or as the number

15 of pixels of ON dots in the periphery of the target

pixel increases. Thereby, it comes to be easily

determined that re-quantization of the quantized level 1

is necessary, and, thereby, the quantized level 1 comes

to be not easily output.

20   When the target pixel level 'level' after

having the error added thereto is not larger than the

threshold THR1, it is determined that re-quantization is

necessary, and this level 'level' is compared with a

threshold relating to the quantized level 1, and is re-

25 quantized. In the third embodiment, it is determined in

a step S24 whether or not the target pixel level 'level' is smaller than 64 which is an approximately intermediate value between the quantization threshold T1 and the output value 85 of the quantized level 1. Then,

5 when the target pixel level 'level' is smaller than 64, the quantized level 0 (output value: 0) is output (in a step S25). However, when it is not smaller than 64, a step S27 is executed, and re-quantization the same as that for the quantized level 2 is performed. (This is in

10 order to prevent texture due to re-quantization from being generated.)

When the quantization output of the quantization part 111 is the quantized level 2 (YES in the step S26) or when the determination result of the

15 step S24 is NO, a threshold THR2 relating to the quantized level 2 is determined (in a step S27). In the third embodiment, the threshold THR2 is calculated by the following equation:

$$THR2 = 128 + (LEVEL - B) \times count \times CNT2$$

20

As mentioned above, 'LEVEL' denotes the target pixel level of the input image data 100, 'count' denotes the number of peripheral dots counted by the peripheral dot

25 counting part 118, 'B' and 'CNT1' are parameters for

determining the input image data level at which the occurrence rate of the quantized level 2 starts decreasing and a slope of the decrease (see FIG. 8), and 'CNT2' is determined as 2, for example. Further, '128'

5   corresponds to the quantization threshold T2.

Then, it is determined in a step S28 whether or not the target pixel level 'level' is smaller than the threshold THR2. When it is not smaller than the threshold level THR2, it is determined that re-

10 quantization is not necessary, and the quantized level 2 (output value: 170) is output as it is (in a step S29). However, when the step S27 is executed after the step S24 is executed, it can be said that the quantized level 1 provided by the quantization part 111 is re-quantized

15 to the quantized level 2. When the target pixel level 'LEVEL' exceeds B, the threshold THR2 increases as this level increases or as the number of pixels of ON dots in the periphery of the target pixel increases. Thereby, it comes to be easily determined that re-quantization of

20 the quantized level 2 is necessary, and, thereby, the quantized level 2 comes to be not easily output.

When the target pixel level 'level' is smaller than the threshold THR2, this level 'level' is compared with a threshold relating to the quantized level 2, and,

25 thus, is re-quantized. In the third embodiment, it is

determined in a step S30 whether or not the target pixel level 'level' is smaller than 150 which is an approximately intermediate value between the quantization threshold T2 and the output value 170 of

5   the quantized level 2. Then, when the target pixel level 'level' is smaller than 150, the quantized level 0 (output value: 0) is output (in a step S31). However, when the target pixel level 'level' is not smaller than 150, the quantized level 3 (output value: 255) is output

10   (in a step S32).

In the third embodiment, re-quantization or output dot control is performed by the output dot control part 111 as describe above. Accordingly, the quantized levels 1, 2 and 3 occur at rates as shown in

15   FIG. 8 with respect to the input image data level. As shown in FIG. 8, as the input image data level increases, the occurrence rate of the quantized level 1 increases. However, when it exceeds the level A, the occurrence rate of the quantized level 1 decreases sharply, and the occurrence rate of the quantized level 2 increases.

20   Further, from the level B, the occurrence rate of the quantized level 2 decreases sharply, and the occurrence rate of the quantized level 3 increases. Further, each of the occurrence rates of the quantized levels 1 and 2

25   does not reach 100 % (the maximum occurrence rates

thereof are determined by the values of A and B used for calculating the thresholds THR1 and THR2).

When the output data 101 for which the occurrence rates of the quantized levels 1 and 2 are
5   controlled is provided to an electrophotographic printer or the like, it is possible to form high-quality images. That is, for light shade regions, graininess is satisfactory because images are formed by the smallest dots of the quantized level 1. For medium shade regions
10   in which the small dots of the quantized level 2 occur, occurrence of the unstable smallest dots is repressed, and images are formed approximately only by the small dots of the quantized level 2. Accordingly, stability and graininess of the images are improved. For dark
15   shade regions in which the large dots of the quantized level 3 occur, occurrence of the small dots is repressed, and images are formed approximately only by the large dots. Accordingly, stability of the images is improved, and, saturation of tonality do not easily occur because
20   the number of dots decreases.

Further, not only the number of dots within the specific region in the periphery of a target pixel but also the shade level of the target pixel are referred to for controlling repressing of the smallest
25   dots and small dots. Also, the output dot for the thus-

repressed pixel is determined by re-quantization.
Accordingly, through all the medium and dark shade
regions, tonality is represented by an appropriate dot
occupation rate, and the number of tones can be
5   increased. Further, the mixing rate of dots is smoothly
switched according to tonality change, and thereby, it
is possible to form images in which switched portions
smoothly couple. This will now be further described
with reference to FIG. 15.

10   The left column of four images shown in FIG.
15 typically show states of dot occurrence in a light
shade region through a dark shade region in a case where
the output image data 101 of the image processing
apparatus in the third embodiment is provided to an
15   electrophotographic printer or the like. The right
column of four images shown in FIG. 15 typically show
states of dot occurrence in a light shade region through
a dark shade region in a case where ordinary 4-level
error diffusion processed data without employing
20   repressing of the smartest dots and small dots is
provided to an electrophotographic printer or the like.

                As shown in the top row of two images of FIG.
15, images are formed by the smallest dots of the
quantized level 1 for light shade regions. Accordingly,
25   isolated dots are not easily remarkable, and, thereby,

graininess is satisfactory.

As shown in images on the left column and second and third rows from the top of FIG. 15, in the third embodiment, for medium shade regions, occurrence

5   of the unstable smallest dots of the quantized level 1 is repressed, and images are formed approximately only by the small dots of the quantized level 2. Accordingly, in comparison to the ordinary 4-level error diffusion processed case (the same rows on the right column in the

10 figure), stability and graininess of the images are satisfactory.

As shown in the bottom-left image of FIG. 15, also for dark shade regions, in the third embodiment, occurrence of the small dots of the quantized level 2 is

15 repressed, and images are formed only by the most stable large dots of the quantized level 3. Accordingly, in comparison to the ordinary 4-level error diffusion processed case (bottom-right image of the figure) in which the small dots of the quantized level 2 are

20 present at high rate together with the large dots, stability of the images is satisfactory.

Further, in the ordinary 4-level error diffusion processed case, the number of dots output is large for dark shade regions. Accordingly, shade is

25 easily saturated due to influence of dot gain (spread of

dot), and ruin of tonality easily occurs. In contrast
to this, in the third embodiment, only the large dots of
the quantized level 3 are output for dark shade regions,
and the number of dots output is small and white pixels

5   which do not output dots also exist. Accordingly, ruin
of tonality is eased in comparison to the ordinary 4-
level error diffusion processed case.

Further, the mixing rate of dots having
different sizes is switched smoothly with respect to

10 change in tonality, thereby, tonality skipping and
incongruity do not occur, and false contours which are
problematic in the ordinary multi-level error diffusion
processed case are not easily generated.

Further, for light shade regions of the input

15 image data levels smaller than A, output of the smallest
dots is not repressed. Accordingly, line cut-out and
line vanishment of characters (or letters) in low-
contrast character portions do not easily occur.

Further, in the third embodiment, it is

20 possible to control the input image data levels (A and
B) at which repressing of occurrence of the quantized
levels 1 and 2 starts individually by the parameters A
and B. Further, in the third embodiment, when the
parameter B is set to 255, it is possible to repress

25 only the quantized level 1 and to control the occurrence

rates of the respective quantized levels same as in the first embodiment. These two points are also same in fourth, sixth and seventh embodiments which will be described later.

5

<<Fourth Embodiment>>

An image processing apparatus in a fourth embodiment of the present invention has a block configuration shown in FIG. 5, but information stored in the peripheral dot information storage part 117,

10 operation of the peripheral dot counting part 118 and processing performed by the output dot control part 119 are different from those of each embodiment described above.

The peripheral dot information storage part

15 117 stores dot information of pixels having undergone quantization, on total two lines, i. e., the line including a target pixel and the immediately proceeding line, similarly to the case of each embodiment described

20 above. However, in the fourth embodiment, not ON/OFF of dots but information indicating the quantized levels of the respective pixels are stored in the peripheral dot information storage part 117.

The peripheral dot counting part 118 refers to

25 the information stored in the peripheral dot information

storage part 117, and, counts each of the number of pixels of the quantized level 1, the number of pixels of the quantized level 2 and the number of pixels of the quantized level 3 of the ten (10) pixels having

5   undergone quantization in the periphery of a target pixel.

Thus, in each embodiment described above, the peripheral ON dots are counted without distinguishing the quantized levels thereof, but in the fourth

10   embodiment, the pixels of ON dots are counted for each quantized level separately.

In the fourth embodiment, re-quantization process or output dot control process, shown in FIG. 9, is performed by the output dot control part 119 on a

15   target pixel having been quantized into the quantized level 1 or 2 by the quantization part 111.

First, the output dot control part 119 determines in a step S40 whether or not the quantization output of the quantization part 111 for a target pixel

20   is the quantized level 1 (output value: 85). When it is not the quantized level 1, it is determined in a step S47 whether or not the quantization output is the quantized level 2. When the quantization output is neither the quantized level 1 nor the quantized level 2,

25   the quantization output of the quantization part 111 is

output as it is (in a step S48).

When the quantization output of the quantization part 111 is the quantized level 1 (YES of the step S40), the number 'a' of dots which is the sum

5   of the numbers of pixels of the quantized levels 1 and 2 provided by the peripheral dot counting part 118 is calculated (in a step S41). Then, this number 'a' of dots is used, and a threshold THR1 relating to the quantized level 1 is determined (in a step S42).

10   In the fourth embodiment, the threshold THR1 is calculated by the following equation:

$$THR1 = 43 + (LEVEL - A) \times a \times CNT1$$

15 Thus, although the number 'count' of dots (see the step S21 of FIG. 7) which is the sum of the numbers of pixels of the quantized levels 1, 2 and 3 is used in the third embodiment, the number 'a' of dots obtained from subtracting the number of pixels of the quantized level

20 3 from this 'count' is used for calculating the threshold THR1 in the fourth embodiment.

Then, it is determined in a step S43 whether or not the target pixel level 'level' is larger than the threshold THR1. When it is larger than the threshold

25 THR1, it is determined that re-quantization for the

quantized level 1 for the target pixel is not necessary,
and the quantized level 1 (output value: 85) is output
as it is (in a step S44). When the target pixel level
'LEVEL' exceeds A, the threshold THR1 increases as this
5   level increases or as the number of pixels of the
quantized levels 1 and 2 in the periphery of the target
pixel increases. Thereby, it comes to be easily
determined that re-quantization of the quantized level 1
is necessary, and, thereby, the quantized level 1 comes
10 to be not easily output.

When the target pixel level 'level' is not
larger than the threshold THR1, it is determined that
re-quantization is necessary, and this level 'level' is
compared with a threshold relating to the quantized
15 level 1, and is re-quantized. In the fourth embodiment,
it is determined in a step S45 whether or not the target
pixel level 'level' is smaller than 64 which is an
approximately intermediate value between the
quantization threshold T1 and the output value 85 of the
20 quantized level 1. Then, when the target pixel level
'level' is smaller than 64, the quantized level 0
(output value: 0) is output (in a step S46). However,
when the target pixel level 'level' is not smaller than
64, a step S49 is executed, and re-quantization the same
25 as that for the quantized level 2 is performed. (This is

in order to prevent texture due to re-quantization from being generated.)

When the quantization output of the quantization part 111 is the quantized level 2 (YES in the step S47) or when the determination result of the step S45 is NO, the number 'b' of dots which is the sum of the numbers of pixels of the quantized levels 2 and 3 provided by the peripheral dot counting part 118 is calculated (in a step S49). Then, using this number 'b' of dots, a threshold THR2 relating to the quantized level 2 is determined (in a step S50). In the fourth embodiment, the threshold THR2 is calculated by the following equation:

$$THR2 = 128 + (LEVEL - B) \times b \times CNT2$$

Thus, although the number 'count' of dots (see the step S27 of FIG. 7) which is the sum of the numbers of pixels of the quantized levels 1, 2 and 3 is used in the third embodiment, the number 'b' of dots obtained from subtracting the number of pixels of the quantized level 1 from this 'count' is used for calculating the threshold THR2 in the fourth embodiment.

Then, it is determined in a step S51 whether or not the target pixel level 'level' (level of the

pixel data 102) is smaller than the threshold THR2.
When it is not smaller than the threshold level THR2, it
is determined that re-quantization is not necessary, and
the quantized level 2 (output value: 170) is output as
5   it is (in a step S52). However, when the step S49 is
executed after the step S45 is executed, it can be said
that the quantized level 1 provided by the quantization
part 111 is re-quantized to the quantized level 2. When
the target pixel level 'LEVEL' exceeds B, the threshold
10 THR2 increases as this level increases or as the number
of pixels of the quantized levels 2 and 3 in the
periphery of the target pixel increases. Thereby, it
comes to be easily determined that re-quantization of
the quantized level 2 is necessary, and, thereby, the
15 quantized level 2 comes to be not easily output.

When the target pixel level 'level' is smaller
than the threshold THR2, this level 'level' is compared
with a threshold relating to the quantized level 2, and,
thus, is re-quantized. In the fourth embodiment, it is
20 determined in a step S53 whether or not the target pixel
level 'level' is smaller than 150 which is an
approximately intermediate value between the
quantization threshold T2 and the output value 170 of
the quantized level 2. Then, when the target pixel
25 level 'level' is smaller than 150, the quantized level 0

(output value: 0) is output (in a step S54). However, when the target pixel level 'level' is not smaller than 150, the quantized level 3 (output value: 255) is output (in a step S55).

5   In the fourth embodiment, through re-quantization for the quantized levels 1 and 2, the quantized levels 1, 2 and 3 occur at rates as shown in FIG. 8 same as in the above-described third embodiment. Accordingly, as described above for the third embodiment,

10 in a case where the output image data 101 is provided to an image forming apparatus such an electrophotographic printer, and images are formed in such a manner that dots are used larger for pixels having higher quantized levels, graininess is satisfactory for light shade

15 regions, stability of images and graininess are satisfactory for medium shade regions, and stability of images is satisfactory for dark shade regions. Further, ruin of tonality is eased. Further, the mixing rate of dots having different sizes is switched smoothly with

20 respect to change in tonality, thereby, skipping of tonality and incongruity do not occur, and false contours which are problematic in the ordinary multi-level error diffusion processed case are not easily generated.

25   In particular, in the fourth embodiment, the

number 'a' of dots obtained from subtracting the number

of large dots from the number of peripheral dots is used

for control of repressing occurrence of the smallest

dots. Accordingly, the smallest dots are not repressed

5 even when the many large dots exist in the periphery of

a target pixel. As a result, jaggy in character (or

letter) regions or edge regions of images can be eased,

and it is possible to produce images having improved

sharpness.

10 Thus, in the fgourth embodimdent, sharpness

which is an advnatage of multi-level error diffusion is

maintained, and, also, stability and tonality for medium

and dark shade regions which may not easily be improved

in multi-level error diffusion can be improved.

15

<<Fifth Embodiment>>

A block configuration of an image processing

apparatus in a fifth embodiment of the present invention

is, as shown in FIG. 10, different from that of the

20 above-described second embodiment, in that a feature

indicating signal 104 indicating a feature of an image

region including a target pixel is input to the output

dot control part 119 in the fifth embodiment.

In the fifth embodiment, through the feature

25 indicating signal 104, it is indicated whether the image

region including a target pixel is either a character (or letter) region or a picture region. A feature determining part which generates the feature indicating signal 104 will be described later. In the fifth

5 embodiment, the feature determining part is provided outside of the apparatus. However, in another embodiment, the feature determining part is provided inside of the apparatus.

Information stored in the peripheral dot

10 information storage part 117, operation of the peripheral dot counting part 118 are same as those in the above-described second embodiment. The output dot control part 119 executes the re-quantization process for the quantized level 1 as shown in FIG. 11.

15 This process will now be described with reference to FIG. 11.

First, the output dot control part 119 determines in a step S60 whether or not the quantization output of the quantization part 111 for a target pixel

20 is the quantized level 1 (output value: 85). When it is not the quantized level 1, the quantization output of the quantization part 111 is output as it is (in a step S61).

When the quantization output of the

25 quantization part 111 is the quantized level 1 (YES in

the step S60), a parameter A for determining a threshold THR is set according to the state of the feature indicating signal 104 (in a step S62). In the fifth embodiment, setting is made such that A = 255 when the feature indicating signal 104 indicates a character region, but setting is made such that A = 30 when the feature indicating signal 104 indicates a picture region. Then, the threshold THR is calculated (in a step S63) by the following equation:

$$THR = 43 + (LEVEL - A) \times count \times CNT$$

There, as mentioned above, 'LEVEL' denotes the target pixel level of the input image data 100, 'count' denotes the number of peripheral dots counted by the peripheral dot counting part 118, and 'CNT' is 2, for example. '43' corresponds to the quantization threshold T1.

Then, it is determined in a step S64 whether or not the target pixel level 'level' after having the diffusion error added thereto is smaller than the threshold THR. When it is not smaller than the threshold THR, it is determined that re-quantization is not necessary, and the quantized level 1 (output value: 85) is output as it is (in a step S65). When the target pixel level 'level' is smaller than the threshold THR,

the target pixel level 'level' is compared with a threshold relating to the quantized level 1, and thus, is re-quantized. In the fifth embodiment, it is determined in a step S66 whether or not the target pixel level 'level' is smaller than 64 which is an approximately intermediate value between the quantization threshold T1 and the output value 85 of the quantized level 1. When it is smaller than 64, the quantized level 0 (output value: 0) is output in a step S67. However, when the target pixel level 'level' is not smaller than 64, the quantized level 2 (output value: 170) is output in a step S68. When the target pixel level 'LEVEL' exceeds A, the threshold THR increases as this level increases or as the number of dots in the periphery of the target pixel increases, and the probability of the quantized level 1 being re-quantized increases. Accordingly, the quantized level 1 is not easily output.

In this process, when the target pixel is a pixel in a character region, setting is made such that A = 255 as mentioned above. Accordingly, the determination result of the step S64 is always NO. That is, it is always determined that re-quantization is not necessary. As a result, the quantization output of the quantization part 111 is output as it is. Accordingly,

occurrence of the quantized level 1 is not repressed.
Thus, in this cased, the process executed is same as the
process executed in the ordinary 4-level error diffusion
process in which the output dot control part 119 is not

5   provided. Accordingly, the respective quantized levels
occur at rates as shown in FIG. 3. Thereby, for
character regions of images, it is possible to form
images having improved sharpness.

On the other hand, when the target pixel is a

10   pixel in a picture region, setting is made such that
A = 30 as mentioned above. Accordingly, when the input
image data level exceeds A, output of the quantized
level 1 is repressed as this level increases or as the
number of dots in the periphery of the target pixel

15   becomes larger. As a result, occurrence rates of the
respective quantized levels are those shown in FIG. 4.
Accordingly, similarly to the case of the above-
described first embodiment, for picture regions of
images, graininess is satisfactory for light shade

20   regions, and stability, graininess and tonality of
images are improved for medium shade regions in
comparison to the case of ordinary 4-level error
diffusion process.

It is also possible to set the parameter A

25   smaller than 255 for character regions, and, to repress

occurrence of the quantized level 1 also for character regions but in a repressing degree weaker than that for picture regions. Generally speaking, it is preferable to perform control such that the degree of repressing

5   occurrence of the quantized level 1 be weaker for character regions than that for picture regions.

In a variant embodiment of the fifth embodiment, a similar re-quantization process is executed only for the quantized level 2, and, occurrence

10   of the quantized level 2 is repressed. In this case, stability, tonality and so forth of images are improved for dark shade regions.

In another variant embodiment of the fifth embodiment, through the feature indicating signal 104,

15   it is indicated whether a picture region including a target pixel is an edge region or a non-edge region. A feature determining part which generates this feature indicating signal 104 will be described later. This feature determining part may be provided outside of the

20   apparatus or may be provided inside of the apparatus. The output dot control part 119 changes a degree of repressing small dots according to whether a target pixel is included in an edge region or a non-edge region. For example, when the target pixel is in an edge region,

25   the parameter A is set to 255, and output of the

quantized level 1 is made not to be repressed. Thereby,
it is possible to form an image having a satisfactory
sharpness for edge regions. On the other hand, when the
target pixel is included in a non-edge region, the

5   parameter A is set to 30, and output of the quantized
level 1 is strongly repressed. Accordingly, it is
possible to form an image having satisfactory stability,
graininess and tonality for non-edge regions.

Further, similarly in a case of a sixth

10 embodiment which will be described later, it is also
possible to re-classify picture regions into photograph
regions and halftone-dot regions, and, to change the
parameter A (parameters A and B in the sixth embodiment)
for the respective regions. Furthermore, it is also

15 possible to aim other feature(s) of images, and to
change the parameter(s) similarly.

The above-mentioned feature determining part
which generates the feature indicating signal 104
indicating distinction between a character region and a

20 picture region will now be described.

In a character region of an image, black
pixels and white pixies occur continuously along an edge
portion of a character. In a halftone-dot region, peaks
in shade occur intermittently and cyclically. In a

25 photograph region, shade change is a little. By

detecting such image features of character region, halftone-dot region and photograph region, it is possible to distinguish between character regions and picture regions (photograph regions and halftone-dot

5   regions).

With regard to such feature determination (discrimination), many related arts are known. For example, as disclosed in Japanese Laid-Open Patent Application No. 3-276966, peaks in shade in an image are

10   detected, and, a region in which cyclicity of the detected peaks is recognized is extracted as a halftone-dot region, a region having a little shade change is extracted as a photograph region, a region which is neither a halftone-dot region nor a photograph region is

15   extracted as a line-drawn region, and 'character region' is indicated for a target pixel included in a line-drawn region but 'picture region' is indicated for a target pixel included in a halftone-dot region or a photograph region. The feature detecting part which executes the

20   above-described process may be used in the relevant embodiment of the present invention. The feature determining part having another configuration may be used instead.

Then, the feature determining part which

25   generates the feature indicating signal 104 indicating

distinction between an edge region and a non-edge region will now be described. Also for such feature determination (discrimination), many related arts are known, and any thereof may be used. For example, four

5   types of differential filters shown in FIGS. 19A, 19B, 19C and 19D are used, and edge amounts are detected for total four directions, i. e., a main scanning direction, a sub-scanning direction, and directions inclined from the main scanning direction by ±45 °, a region in which

10   the absolute value of the edge amount exceeds a predetermined threshold in any direction is determined as an edge region, and a region other than such a region is determined as a non-edge region. The feature determining part which executes the above-described

15   process may be used.

A method of detecting the edge amount by using the differential filters shown in FIGS. 19A through 19D is to obtain the sum of the values obtained from multiplying image data of pixels surrounding a target

20   pixel at pixel positions shown in each of the filters shown in FIGS. 19A through 19D by the corresponding coefficients shown in the figures, respectively, for example.

25   <<Sixth Embodiment>>

An image processing apparatus in a sixth embodiment according to the present invention has a block configuration shown in FIG. 10 the same as that of the above-described fifth embodiment. However, the

5 processing performed by the output dot control part 119 is different from that of the fifth embodiment, as shown in FIG. 12.

The feature indicating signal 104 indicates, similar to the feature indicating signal 104 of the

10 fifth embodiment, whether a image region including a target pixel is a character region or a picture region.

The process executed by the output dot control part 119 of the sixth embodiment will now be described with reference to FIG. 12.

15 First, the output dot control part 119 determines in a step S70 whether or not the quantization output of the quantization part 111 for a target pixel is the quantized level 1 (output value: 85). When it is not the quantized level 1, it is determined in a step

20 S77 whether or not the quantization output of the quantization part 111 is the quantized level 2. When it is neither the quantized level 1 nor the quantized level 2, the quantization output of the quantization part 111 is output as it is (in a step S85).

25 When the quantization output of the

quantization part 111 is the quantized level 1 (YES of the step S70), a parameter A for determining a threshold THR1 relating to the quantized level 1 is set according to the state of the feature indicating signal 104 in a step S71. In the sixth embodiment, setting is made such that A = 255 when the feature indicating signal 104 indicates "character region" but setting is made such that A = 30 when the feature indicating signal 104 indicates "picture region". Then, the threshold THR1 is calculated in a step S72 by the following equation:

$$THR1 = 43 + (LEVEL - A) \times count \times CNT1$$

As mentioned above, 'LEVEL' denotes the target pixel level of the input image data 100, 'count' denotes the number of peripheral dots counted by the peripheral dot counting part 118, 'A' and 'CNT1' are parameters for determining the input image data level at which the occurrence rate of the quantized level 1 starts decreasing and a slope of the decrease (see FIG. 8), and CNT1 is determined as 2, for example. Further, '43' corresponds to the quantization threshold T1.

Then, it is determined in a step S73 whether or not the target pixel level 'level' (level of the image data 102) is larger than the threshold THR1. When

it is larger than the threshold THR1, it is determined

that re-quantization for the quantized level 1 for the

target pixel is not necessary, and the quantization

output of the quantization part 111, that is, the

5   quantized level 1 (output value: 85) is output as it is

(in a step S74).

When the target pixel level 'level' after

having the error added thereto is not larger than the

threshold THR1, it is determined that re-quantization is

10   necessary, and this level 'level' is compared with a

threshold relating to the quantized level 1, and is re-

quantized. In the sixth embodiment, it is determined in

a step S75 whether or not the target pixel level 'level'

is smaller than 64 which is an approximately

15   intermediate value between the quantization threshold T1

and the output value 85 of the quantized level 1. Then,

when it is smaller than 64, the quantized level 0

(output value: 0) is output (in a step S76). However,

when it is not smaller than 64, a step S78 is executed,

20   and re-quantization the same as that for the quantized

level 2 is performed. (This is in order to prevent

texture due to re-quantization from being generated.)

When the target pixel level exceeds A, the threshold

THR1 increases as this level increases or as the number

25   of pixels of dots in the periphery of the target pixel

increases. Thereby, the quantized level 1 comes to be not easily output.

When the quantization output of the quantization part 111 is the quantized level 2 (YES in the step S77) or when the determination result of the step S75 is NO, a parameter B for determining a threshold THR2 relating to the quantized level 2 is determined according to the state of the feature indicating signal 104 in a step S78. In the sixth embodiment, setting is made such that B = 255 when the feature indicating signal 104 indicates "character region" but setting is made such that B = 100 when the feature indicating signal 104 indicates "picture region". Then, the threshold THR2 relating to the quantized level 2 is calculated (in a step S79) by the following equation:

$$THR2 = 128 + (LEVEL - B) \times count \times CNT2$$

As mentioned above, 'LEVEL' denotes the target pixel level of the input image data 100, 'count' denotes the number of peripheral dots counted by the peripheral dot counting part 118, 'B' and 'CNT2' are parameters for determining the input image data level at which the occurrence rate of the quantized level 2 starts

decreasing and a slope of the decrease (see FIG. 8), and CNT2 is determined as 2, for example. Further, '128' corresponds to the quantization threshold T2.

Then, it is determined in a step S80 whether or not the target pixel level 'level' is smaller than the threshold THR2. When it is not smaller than the threshold level THR2, it is determined that re-quantization is not necessary, and the quantized level 2 (output value: 170) is output as it is (in a step S81). However, when the step S78 is executed after the step S75 is executed, it can be said that the quantized level 1 is re-quantized to the quantized level 2.

When the target pixel level 'level' is smaller than the threshold THR2, this level 'level' is compared with a threshold relating to the quantized level 2, and, thus, is re-quantized. In the sixth embodiment, it is determined in a step S82 whether or not the target pixel level 'level' is smaller than 150 which is an approximately intermediate value between the quantization threshold T2 and the output value 170 of the quantized level 2. Then, when the target pixel level 'level' is smaller than 150, the quantized level 0 (output value: 0) is output (in a step S83). However, when the target pixel level 'level' is not smaller than 150, the quantized level 3 (output value: 255) is output

(in a step S84). When the target pixel level exceeds B, the threshold THR2 increases as this level increases or as the number of pixels of dots in the periphery of the target pixel increases. Thereby, the quantized level 2

5   comes to be not easily output.

In this process, when the target pixel is a pixel in a character region, setting is made such that A = B = 255, as mentioned above. Accordingly, the determination results in the steps S73 and S80 are

10   always NO, and output of the quantized levels 1 and 2 is not repressed. That is, it is always determined that re-quantization is not necessary. As a result, the quantization output of the quantization part 111 is output as it is. Accordingly, occurrence of the

15   quantized levels 1 and 2 is not repressed. Thus, in this case, the process executed is same as the process executed in the ordinary 4-level error diffusion process in which the output dot control part 119 is not provided. Accordingly, the respective quantized levels occur at

20   rates as shown in FIG. 3. Thereby, for character regions of images, it is possible to form images having improved sharpness.

On the other hand, when the target pixel is a pixel in a picture region, setting is made such that

25   A = 30 and B = 100, as mentioned above. Accordingly,

when the input image data level exceeds A, output of the quantized level 1 is repressed. Further, when the input image data level exceeds B, output of the quantized level 2 is repressed. As a result, occurrence rates of

5 the respective quantized levels are those shown in FIG. 8. Accordingly, similarly to the case of the above-described third embodiment and so forth, for picture regions of images, graininess is satisfactory for light shade regions, and stability, graininess and tonality of

10 images are improved for medium and dark shade regions.

Similarly to the above-described fifth embodiment, it is also possible to set the parameters A and B smaller than 255 for character regions, and, to repress occurrence of the quantized levels 1 and 2 also

15 for character regions but in repressing degrees weaker than those for picture regions.

<<Seventh Embodiment>>

A block configuration of an image processing

20 apparatus in a seventh embodiment according to the present invention is, as shown in FIG. 13, different from that of the above-described sixth embodiment, in that an output mode signal 106 indicating an output mode is input to the output dot control part 119. This

25 output mode signal 106 is provided from an operation

panel not shown in the figure operated by a user, for
example. Information stored in the peripheral dot
information storage part 117 and operation of the
peripheral dot counting part 118 are the same as those
5   of the above-described first embodiment. Processing
performed by the output dot control part 119 is the same
as that in the above-described sixth embodiment except
that the values of parameters A and B for determining
the thresholds THR1 and THR2 are changed according to
10 the output mode specified, and, therefore, will now be
described using FIG. 12.

In the step S71, the output control part 119
sets the parameter A to a value according to the
specified output mode. Further, in the step S78, the
15 output control part 119 sets the parameter B to a value
according to the specified output mode. In the seventh
embodiment, as the output mode, as shown in FIG. 14, any
one of a 'character mode' suitable for outputting images
in which shade changing points of characters (or
20 letters) or the like are intended to be reproduced with
high resolution, a 'photograph mode' suitable for
outputting images having a little shade change such as
photographs, a 'character/photograph mode' suitable for
outputting images of both characters and photographs,
25 and a 'printed photograph mode' suitable for outputting

halftone-dot images such as printed matters. Then, according to the thus-specified output mode, the parameters A and B are set, as shown in FIG. 14.

When the character mode is selected, the

5 parameters A and B are set to 255 as shown in the figure. Accordingly, occurrence of the quantized levels 1 and 2 is not repressed, and the process same as ordinary 4-level error diffusion is executed. Thereby it is possible to form images having superior sharpness.

10 When the photograph mode is selected, the parameters A and B are set to small values, i. e., 30 and 100, respectively, and occurrence of the quantized levels 1 and 2 is strongly repressed as shown in FIG. 8. Accordingly, it is possible to form images having

15 superior graininess, stability and tonality.

When the character/photograph mode is selected, the parameter A is set to 30, and, thereby, occurrence of the quantized level 1 is strongly repressed, but the parameter B is set to 150 which is somewhat large, and,

20 thereby, occurrence of the quantized level 2 is repressed weakly. Accordingly, it is possible to form satisfactory images for both characters and photographs.

When the printed photograph mode is selected, the parameter A is set to 60 which is large, and thereby,

25 occurrence of the quantized level 1 is weakly repressed,

and, the parameter B is set to 255, and thereby, occurrence of the quantized level 2 is not repressed. Accordingly, it is possible to form halftone-dot images such as those of printed matters satisfactorily.

5   Although each embodiment described above performs 4-level quantization, the present invention can be easily applied to an image processing apparatus which performs multi-level quantization of three levels or five or more levels. For example, when image data is 3-

10   level quantized into 0, 1 and 2, occurrence of the quantized level 1 may be repressed similarly. Further, when image data is 5-level quantized into 0, 1, 2, 3 and 4, occurrence of the quantized levels 1, 2 and 3 is repressed similarly. Also in a case of multi-level

15   quantization of the number of levels more than this, a similar manner may be considered of course.

The image processing apparatus in each of the above-described embodiments and variant embodiment may be achieved by software using a general-purpose or

20   special-purpose computer such as that shown in FIG. 20.

In this case, a program for achieving the functions of the respective parts of the image processing apparatus is read from one of various recording media 1310 such as a floppy disk, an optical

25   disk, a magneto-optical disk, a semiconductor storage

device, and so forth through a suitable drive device 1300, or received from an external computer via a network through a communication device 1400, is then loaded in a main memory 1200, and is then executed by a

5   CPU 1100 in a well-known manner.

Accordingly, it is possible to achieve the image processing apparatus according to the present invention by the general-purpose or special-purpose computer. Storage areas of the main memory may be used

10   as line memories and so forth necessary for storing various data, for example.

Such various computer-readable recording media (floppy disk, optical disk, magneto-optical disk, semiconductor storage device, and so forth) in which

15   such a program is recorded are included in the present invention.

The image processing apparatus in each of the above-described embodiments and variant embodiments thereof may be incorporated in apparatuses relating to

20   image formation such as a printer, a display device, and so forth, apparatuses relating to image reading such as a scanner, a facsimile machine, and so forth, and apparatuses relating to both image reading and image formation such as digital copier and so forth.

25   As one example thereof, a digital copier to

which the present invention is applied will now be described (as an eighth embodiment of the present invention).

5   <<Eighth Embodiment>>

FIG. 16 shows a general sectional view of the digital copier in the eighth embodiment.

The digital copier shown in FIG. 16 includes an image reading part 400 which optically scans an

10   original image and reads it, a laser printer 411 which serves as an image forming apparatus, and a circuit part 550 (see FIGS. 17 and 18) not shown in the figure, and an operation panel, also not shown in the figure, for an operator or user to input various instructions to the

15   copier (for example, an instruction of the output mode in the above-described seventh embodiment).

The image reading part 400 illuminates an original image sheet placed on a flat original table 403 by an illuminating lamp 502, forms an image from a

20   reflected light image from the original image sheet onto an image sensor 507 such as a CCD by mirrors 503 through 505 and a lens 506. And also, by sub-scanning the original image sheet by moving the illuminating lamp 502 and mirrors 503 through 505, the image reading part 400

25   reads image information of the original image sheet, and

converts it into an electric image signal. The analog image signal output from the image sensor 507 is input to the circuit part 550 (FIGS. 17, 18), and is processed thereby. Image data output from the circuit part 550 is

5 input to the laser printer 411 which then form an image.

In the laser printer 411, a writing optical unit 508 converts image data input from the circuit part 550 into an optical signal, and exposes an image carrying body made of a photosensitive body, for example,

10 a photosensitive body drum 509. Thereby, an electrostatic latent image corresponding to the original image is formed on the photosensitive body drum 509.

The writing optical unit 508, for example, drives a semiconductor laser according to the above-

15 mentioned image data so as to cause it to emit thus-intensity-modulated laser light, deflects the laser light by a rotational polygon mirror 510, and illuminates the photosensitive body drum 509 by the laser light through an f/θ lens and a reflective mirror

20 511.

The photosensitive body drum 509 is driven to rotate in a direction indicated by the arrow clockwise by a driving part. After being charged uniformly by a charger 512, the photosensitive body drum 509 is exposed

25 by the writing optical unit 508, and thus has the

electrostatic latent image formed thereon.

The electrostatic latent image on the photosensitive body drum 509 is developed by a developing device 513, and becomes a toner image.

5 Further, a paper sheet is supplied by any of a plurality of paper feeding parts 514 through 518 and hand-inserting paper feeding part 519 to a registration roller 520. The registration roller 520 sends out the paper sheet in timing to the toner image on the

10 photosensitive body drum 509.

A transfer belt 521 has a transfer bias applied thereto by a transfer power source, transfers the toner image on the photosensitive body drum 509 onto the paper sheet, and carries the paper sheet. The paper

15 sheet having had the toner image transferred thereto is then carried to a fixing part 522 by the transfer belt 521, and the toner image is fixed onto the paper sheet thereby, which is then ejected to an ejecting tray 523.

The photosensitive body drum 509 is cleaned by

20 a cleaning device 524 after the toner image thereon is transferred, and electricity of the photosensitive body drum 509 is removed by an electricity removal device 525. Thus, the photosensitive body drum 509 is prepared for a subsequent image forming operation.

25 FIG. 17 shows a block diagram after

simplifying one example of the above-mentioned circuit
part 550 of the digital copier.

Input to the circuit part 550 is, for example,
an analog image signal obtained from reading the

5   original image in 600 dpi by the image sensor 507 of the
image reading part 400. The level of this analog signal
is adjusted by an AGC circuit 551, and, then, an A-D
converting circuit 552 converts the thus-obtained analog
signal into a digital image signal representing each

10 pixel by 8 bits.

Further, a shading correction circuit 553
corrects for each pixel of the image sensor 507
variation in sensitivity and illumination.

Then, the image data is sent to a filter

15 processing circuit 554, undergoes MTF correction, for
example, and then, undergoes smoothing filter processing
for representing a halftone image smoothly. The thus-
obtained image data is input to a γ (gamma) correction
circuit 555 which then performs γ correction on the

20 input image data for converting the image data to have
writing shade.

The image data having undergone the γ
correction is input to a halftone processing part 556.
The image processing apparatus in any of the above-

25 described embodiments and variant embodiments thereof of

the present invention is used as this halftone
processing part 556

The output image data provided by the halftone
processing part 556 is sent to a light-emitting driving
5   control part of a semiconductor laser inside of the
above-mentioned writing optical unit 508. Because the
halftone processing part 556 executes the above-
described multi-level quantization process, it is
possible to reproduce the image read from the original
10   image sheet with high image quality.

In a case where the image processing apparatus
in any of the above-described fifth and sixth
embodiments and variant embodiments thereof is used as
the halftone processing part 556, the feature
15   determining part which provides the feature indicating
signal 104 indicating distinction between character
region/picture region or distinction between edge
region/non-edge region may be provided inside the
halftone processing part 556 or may be provided
20   antecedent to the halftone processing part 556. For
example, the feature determining part 560 may be
provided at the position shown in FIG. 18.

Actually, the digital copier can perform
processing such as image-size changing processing,
25   background removal processing, flare removal processing,

other image edition processing on image data. However, description thereof is omitted.

Further, the present invention can be easily applied also to the digital copier having an image
5 reading part which moves a original table, and a digital copier having an image forming part other than a laser printer

An image processing apparatus in another embodiment of the present invention has a configuration
10 in which, although not shown in figures, as a scanner or a facsimile, a reading part such as the image reading part 400 of above-described digital copier is added to the image processing apparatus in any of the above-described first through seventh embodiments and variant
15 embodiments thereof.

An image processing apparatus in another embodiment of the present invention has a configuration in which, although not shown in figures, an image forming part such as the laser printer 411 of above-
20 described digital copier is added to the image processing apertures in any of the above-described first through seventh embodiments and variant embodiments thereof.

The present invention is not limited to the
25 above-described embodiments, and variations and

modifications may be made without departing from the scope of the present invention.

The present application is based on Japanese priority application No. 11-353625, filed on December 13,

5 1999, the entire contents of which are hereby incorporated by reference.